Energy Analysis on the Processing of Green Tea

Wahyu K Sugandi[1]✉, Kralawi Sita[2], Totok Herwanto[1], Shida Habsari[1]

[1]Department of Agricultural Engineering and Biosystem, Faculty of Agro-Industrial Tecnology, Universitas Padjadjaran, Jatinangor, INDONESIA
[2]Gambung Research Institute for Tea and Cinchona. Mekarsari Village, District Pasirjambu, Bandung Regency, West Java, INDONESIA

✉Corresponding Author:
wahyu.sugandi@unpad.ac.id

ABSTRACT

Energy analysis on processing of green tea at green tea factory. Research Institute for Tea and Cinchona (RITC) Gambung was conducted to analyze energy use and identify energy use. Energy analysis is calculated based on the use of biological energy, direct energy, and indirect energy at each process of green tea processing started from withering to packaging activities. This research was conducted with descriptive analysis method by measure and calculate the energy usage for each process. The results showed that the total of energy use in green tea 51.141 MJ/kg. Indirect energy is the biggest energy contributor to the use of total energy (with indirect energy) with energy values reached 46.764 MJ/kg. Meanwhile, the total use of biological energy is 0.01 MJ/kg and the total use direct energy is 4.366 MJ/ kg. The results of the energy analysis assessment show that energy savings can be made by maintaining and replacing the damaged parts of the machine especially maintenance of burner in withering process, changing the concept of tea packing to 55 kg of tea/pack, changing the capacity of ball tea machine in the second drying process to 400 kg of dry tea to save the electricity supply system. The results of SWOT analysis showed in quadrant I, where the strategy in this quadrant is S-O strategy, which is growth-oriented strategy.

1. INTRODUCTION

Energy is the ability to carry out a business and is the main factor that works as a driving force for human activities, industry and the economy of a country (Ang & Choong, 2014). The development of the world economy and the increase in developed and developing countries have caused the demand for global energy to increase (Setiawan, 2010). Indonesia is one of the countries with the most energy needs in Southeast Asia, reaching 44% of the total energy demand in the Southeast Asia region, followed by Malaysia with 23% and Thailand with 20% (Biantoro, 2017). Domestic use of fossil energy is still high at 96% (48% oil, 18% gas and 30% coal) of the total energy consumption (DEN, 2014).

The industrial sector is estimated to dominate the demand for fossil energy with an increase of 2.7% per year until the year 2035 (Nurudin, 2016). The increase in the use of energy in the industrial sector in the last 10 years occurred due to a very fast structural transformation process from the agricultural sector to the industrial sector. The increase in the number of industries occurs either by the addition of the number of factories or the construction of new industries. It is predicted that this will lead to waste of energy use in the industrial sector. The increase in energy demand will result in an increase in CO_2 gas emissions resulting from burning energy sources, especially if there is no selection for low-carbon fuel types nor the use of effective and environmentally friendly technology.

Tea (*Camiellia sinensis* L.) plantations are one of the agricultural sub-sectors that have a major role in producing export commodities. According to the International Tea Committee (2017), Indonesia is the 7th tea producing country in the world after China, India, Kenya, Sri Lanka, Turkey, and Vietnam. In 2016, Indonesia's total tea production reached 125,000 tons of the world's total tea production. Most of Indonesia's tea production (65%) is sent for the export market. Most of Indonesia's tea export volume (94%) is still in the form of dry leaves (Anova, 2017). Tea is an annual plant that has various properties, including as an ingredient in refreshing drinks, industrial materials, pharmaceuticals and cosmetics (Mancini *et al*, 2017). The health benefits of tea come from the main elements of tea such as polyphenols, tannins, caffeine, and essential oils (Kusuma, 2008). Tea products in Indonesia are divided into 3 parts, namely black tea, oolong tea, and green tea. According to Rohdiana (2015), green tea is tea that has fairly good health benefits.

Based on data from the BPS (2017), 70.54% of the largest tea production is in West Java. One of them is the Gambung Research Institute for Tea and Cinchona (PPTK Gambung), which has a Green Tea Factory in the Pasir Jambu area, West Java. PPTK Gambung is a Center for Excellence in Science and Technology (PUI) under the Ministry of Research, Technology and Higher Education. The competence of the the PPTK Gambung is to focus on research and development along with increasing opportunities and challenges. The green tea production process at the PPTK Gambung Green Tea Factory uses a panning method with processing stages including withering, cooling, rolling, drying, and packing (Santoso, 2008). Green tea processing involves workers and involves the use of new machines whose energy efficiency has not been analyzed at this time.

Energy requirements in the green tea processing at the PPTK Gambung Green Tea Factory have not yet calculated the amount of energy used. Energy audit or energy analysis is one method to provide an overview of energy use and identify when there is excessive energy use (Taulo & Sebitosi, 2016). Energy analysis is also intended to increase the efficiency of green tea processing by making improvements that can be made to the processing (Setiawan, 2010). Previously, PPTK Gambung used firewood for the withering process, resulting in a waste of energy, and currently using wood pellets to replace the firewood. The results of the energy audit conducted at PPTK Gambung will then be used as a guideline to obtain a better level of efficiency and can increase the competitiveness of green tea products through energy conservation using several alternative energy sources in the PPTK Gambung Green Tea Factory. The purpose of this study is to analyze energy use for each stage of the green tea processing process at the PPTK Gambung Green Tea Factory so that it can be seen the appropriate strategic steps in order to increase the efficiency of energy use for the green tea processing process in the PPTK Gambung Green Tea Factory.

2. MATERIALS AND METHODS

2.1. Materials and Equipment
The tools and materials used in this research were primary data and secondary data for green tea processing. The primary data were obtained from direct measurements, which included observations, interviews with PPTK Gambung, and calculations. While the secondary data was started from the schedule of activities, the time required for each processing process, the number of employees, processing machine specifications, and literature studies.

2.2. Method
The research method used in this research was descriptive research method, which is a selection method that collects data, then arranges it systematically, then describes variable by variable (Hasan, 2002). The variables studied in this study included biological energy, direct energy, and indirect energy. Each type of energy at each stage of the green tea processing process was described in the form of tables and diagrams so that the amount of energy use can be calculated.

2.3. Research Stages
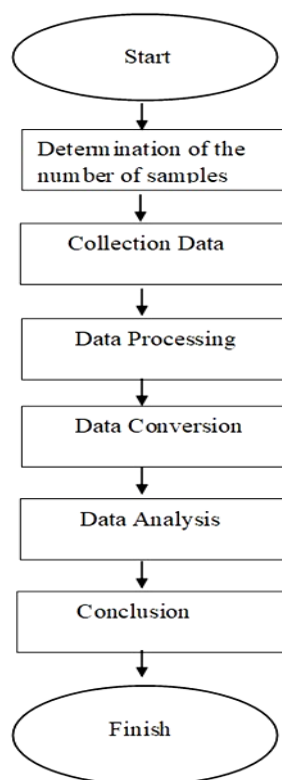The stages of this research were carried out in several stages as presented in Figure 1.

Figure 1. The stages of green tea processing

2.4. Number of Samples
The number of samples was determined using the purposive sampling method which was conducted by interviewing employees who understood the green tea processing process at the PPTK Gambung Green Tea Factory. Purposive sampling is a sample

selected based on the researcher's assessment that the respondent is the best party to be used as a research sample (Notoatmodjo, 2005). In this study, the number of samples was a saturated sample. Saturated sampling is a sampling technique where all members of the population are used as samples (Sugiono, 2011). Another term for saturated sample is census. Based on this study, due to the small size of population, all members of the population in the PPTK Gambung green tea factory, namely 34 respondents were involved.

2.5. Data collection
Data collection was carried out to observe and collect data on energy use during the green tea processing. This was done by referring to the number of workers, employee activity schedules, types of activities and the time required for each type of activity, the number and type of machine tools used in green tea processing, all aspects involved in the green tea processing such as electricity consumption, materials fuel, and identify the form and amount of energy in each stage of the process.

2.6. Data Processing
Data processing was carried out when the data collection process has been completed. Existing data is processed first for initial evaluation with the aim of obtaining complete data so that it can be continued to the next process. Data processing aimed to convert data into energy units. The conversion of data into energy units was carried out through calculations as in the following.

2.6.1. Biological Energy
According to Abdullah *et al*. (1990), biological energy is calculated by the following equation:

$$EBS = HOK \times JK \times Cb \times RD \tag{1}$$

where *EBS* is the biological energy consumption (in this case is operational workers) for the green tea processing (MJ/kg), *HOK* is the number of working days per ton of product (d/kg), *JK* is the number of working hour per day (h/d), *RD* is the yield of ongoing activities (%), *Cb* is the coefficient value of biological energy (MJ/hour)

2.6.2. Direct Energy
According to Abdullah *et al*. (1990), direct energy processing using fuel is analyzed by the following equation:

$$ELT = (KL \times CL \times RD)/CH \tag{2}$$

where *ELT* is the fuel energy used in the production process (MJ/kg), *KL* is the fuel consumption (kg/h), *CL* is the unit value of fuel energy (MJ/kg), and *CH* is the effective field capacity of machines (kg/h).

2.6.3. Electrical Energy
The use of electricity in the green tea processing was analyzed by the following equation (Cervinka, 1980):

$$EL = KL \times NEL \tag{3}$$

where *EL* is the electrical energy used in the processing (MJ/kg), *KL* is the electricity demand in the processing (kWh/kg), and *NEL* is the value of electrical energy per kWh (MJ/kWh).

2.6.4.Indirect Energy

The indirect energy needs of agricultural equipment and machines used in the post-harvest process were calculated using the following equation (Abdullah *et al.*, 1990):

$$EAS = \frac{\{M1\,(cem+cef)x\,(0.82+(0.3\,x\,TAR)xRD}{CH\,x\,N} \qquad (4)$$

where *EAS* is the indirect energy used from the production tool or machine (MJ/kg), *M*1 is the total mass of the machine (kg), cem is the unit value of indirect energy production of raw materials (MJ/kg), cef is the unit value of indirect energy manufacturing (MJ/kg), *TAR* is the percentage value of the total accumulated repair and maintenance usage (%), *RD* is the yield of ongoing activities (%), *N* is the economic life of the tool or machine (hours).

2.7. Data Analysis

Data analysis was carried out to include:

1. All observational data were distinguished according to the steps of process and were divided into 6 parts, namely withering, cooling, rolling, drying I, drying II, and packing;
2. The observed data was processed by converting it into energy units using the existing equations;
3. The amount of energy used in each stage of the green tea processing was analyzed;
4. Energy yield data in each production activity were summed up and divided by the total production output from the green tea processing;
5. Total energy consumption in green tea processing at PPTK Gambung was analyzed; and
6. Data on energy saving and conservation opportunities as well as analyzing the potential of alternative energy sources found in PPTK Gambung was analyzed.

In this case, the process analysis method was used because it can provide an overview of the energy use in each stage to produce the final product. Each stage of the process or work requires an input and each input indicates the use of energy. After the process analysis, it was then described about optimizing energy use and increasing production in the green tea processing using SWOT (strengths, weaknesses, opportunities, threats) analysis. The SWOT analysis for PPTK Gambung Green Tea Factory were as follows:

1.Strengths

a) The location of the green tea processing plant is close to the tea garden
b) The processing tools and machines used are still in new condition
c) Have a competent workforce
d) Have good quality green tea
e) The fuel used for green tea processing is ideal to produce good quality green tea

2.Weaknesses

a) The sorting process is carried out elsewhere
b) The process of packing dry tea is still done manually
c) Processing tools and machines are prone to damage if not properly maintained

d) The available tools and machines has not able to meet the needs because the low input capacity

e) Poor road access from the plantation to the processing plant

3. Opportunities

a) The selling price of green tea is higher than black tea

b) There are still few green tea processing factories in Indonesia

c) The market demand for green tea is high

d) Cooperation with other factory (PT. KBP Chakra) in producing green tea

e) PPTK Gambung Green Tea Factory is widely used as a research facility by various institutions and universities in Indonesia

4. Threats

a) Unstable fuel and electricity prices

b) Applying of maximum residue level (MRL) by green tea importing countries

c) Weather that affects the quality of raw materials

d) Uncertain plant pests that reduce the quality of tea shoots

e) Low public awareness of the benefits of consuming green tea

3. RESULTS AND DISCUSSION

3.1. Tea Processing Yield

The post-harvest process of agricultural products always pays attention to the level of yield. Post-harvest processing is part of agricultural production. In the processing of tea commodities, especially green tea, the yield value can be calculated by comparing the mass of the processing product (dried green tea) with the mass of the harvest (fresh shoots raw material) before entering the processing process (Hu *et al.*, 2003). The calculated yield value is the average yield value of 7 processing times. The mass of raw material for fresh shoots before processing is 14,579 tons. Meanwhile, the mass of green tea from processing and after drying is 3, 308 tons, so that after calculating the yield in the green tea processing process, it is 22.7%.

The calculation of the yield of green tea processing is obtained from the comparison between the mass of green tea (output) and the mass of fresh tea (input). This yield calculation is carried out for each stage of the green tea processing process, so that the values of withering yield, cooling yield, rolling yield, drying yield I, drying yield II, and packing yield will be obtained. The yield of each stage of the green tea processing process can be seen in Table 1.

Table 1. Yield of green tea processing based on process stages

	Yield		
Proses	**Input**	**Output**	**Yield**
	(ton)	**(ton)**	
Withering	14.578	10.251	70.32%
Cooling	10.251	9.987	97.42%
Rolling	9.987	9.788	98.01%
Drying I	9.788	8.348	85.29%
Drying II	8.348	3.308	39.63%
Packing	3.308	3.308	100%
Total			**22.7%**

The process that results in an important reduction of water content is the withering process, which is 70.32%, the initial drying process 85.29%, and the second drying process 39.63%. This is due to the significant reduction in the water content of the tea in the three processes. The reduction in water content in the withering process is caused throughout the withering process, in the rotary panner there is a process of evaporation of water on the surface of the tea leaves, which is then discharged through a fan. Drying of green tea is usually carried out in 2 stages of drying, where the water content in the tea will decrease at each stage of drying due to the need for hot temperatures. In the initial drying process, the water content decreased from 46.5% to 37.1%. Furthermore, in the second drying process with a high temperature there was a significant reduction in water content until there was a change from tea shoots to tea powder with an average water content of 4.7%. The yield on the cooling process is 97.42% and the yield of rolling is 98.01% and this value has no significant effect.

3.2. Green Tea Processing Energy Analysis

Energy analysis includes all processes of green tea processing, starting from the withering process of the tea shoots to the green tea packaging process. The analyzed energy includes the use of biological energy, the use of direct energy in the form of fuel, the use of electrical energy, and the indirect energy of tools and machines. Overall green tea processing activities consist of withering. cooling, rolling, drying I, drying II, and packing. The use of direct and indirect energy in the green tea processing carried out at the PPTK Gambung Green Tea Factory as a whole was 51.1.41 MJ/kg (Table 2).

Table 2. Total green tea processing energy at PPTK Gambung Green Tea Factory

Proses	Energy consumption (MJ/kg)				
	Biological Energy	Direct Energy	Indirect Energy	Total Energy	Persentage of Total (%)
Witheing	0.002	2.028	15.333	17.364	33.953
Cooling	0.0008	0.060	2.308	2.369	4.634
Rolling	0.0008	0.165	10.222	10.389	20.315
Drying I	0.002	1.069	10.195	11.266	22.030
Drying II	0.002	1.061	8.391	9.435	18.449
Packing	0.004	0	0.312	0.316	0.618
Total	**0.01**	**4.366**	**46.764**	**51.141**	**100**

Direct energy needs consist of fuel and electrical energy. The electrical energy consumption for the withering process is 0.093 MJ/kg, cooling 0.06 MJ/kg, rolling 0.165 MJ/kg, drying I 0.135 MJ/kg and drying II 0.274 MJ/kg. Meanwhile, fuel energy consumption for withering is 1.935 MJ/kg, drying I is 0.933 MJ/kg, and drying II is 0.767 MJ/kg.

Based on the stages of the process, the largest energy use is found in the energy use of the withering process, which is 17,364 MJ/kg tea shoots or 33.953% of the total energy requirement for green tea processing, and the smallest energy use is in the packaging process, which is 0.316 MJ/kg or 0.618%. of the total energy requirements for green tea processing. For comparison, the processing of orthodox black tea at PT. Perkebunan Nusantara VIII Kebun Gedeh requires biological energy and direct energy of 11,162 MJ/kg in the withering process and in the packing process of 0.321 MJ/kg (Herwanto *et al.*, 2018). It can be concluded that the green tea processing process at

the PPTK Gambung Green Tea Factory can save 9.131 MJ/kg in the withering process and 0.318 MJ/kg in the packaging process.

The total energy use for green tea processing at the Green Tea Factory PPTK Gambung is 51.141 MJ/kg with an average yield of 14,579 kg/day. When compared with the results of orthodox black tea processing at PT. Perkebunan Nusantara VIII Kebun Gedeh (Herwanto *et al.*, 2018) which requires a total energy of 73,034 MJ/kg with an average yield of 8,128 kg/day, it can be concluded that with an average yield of 14,579 tons/day of green tea processing in PPTK Gambung could save 21,893 MJ/kg from processing orthodox black tea at PT. Perkebunan Nusantara VIII Kebun Gedeh.

3.3. SWOT analysis

SWOT analysis is a classic strategic planning instrument using a framework of strengths, weaknesses, opportunities, and threats. This instrument provides a simple method for estimating the best way to implement a strategy (Sabbaghi *et al.*, 2004). Based on the calculation of the relationship between the S-O factors (growth oriented strategy) in the 1st quadrant. The result of reducing strengths and weaknesses (S-W) as the X axis is positive, which is 0.593. Meanwhile, the reduction of opportunities and threats (O-T) as the Y axis has a positive value of 0.433. The coordinates (X, Y) are then positioned in the SWOT quadrant to determine the general strategy used so that the green tea processing process can take place more efficiently.
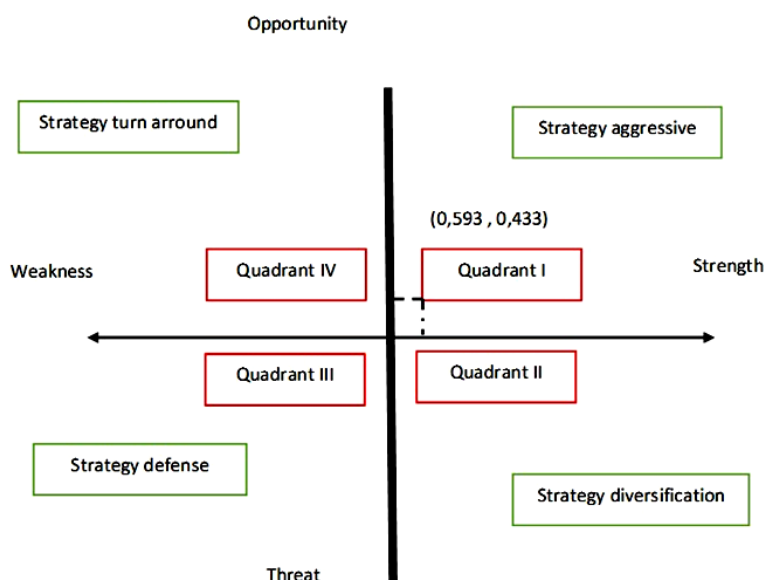

Figure 2. Results from SWOT analysis for PPTK Gambung Green Tea Factory

Conclusions can be drawn regarding general strategies for energy saving and increasing production in green tea processing in the PPTK Gambung Green Tea Factory area, including:
  * PPTK Gambung green tea factory must maintain good green tea quality by continuing to use ideal fuels.
  * In order to increase the selling price of green tea and meet the high demand of the green tea market.
  * New gardens, green tea factories and processing machines can be used as

research facilities by various institutions and universities in Indonesia in order to detect as early as possible the deficiencies in tea factories.
* A competent workforce in their field can support the cooperation between PPTK Gambung Green Tea Factory and PT. KBP Chakra in producing high quality green tea.
* The small number of green tea processing factories in Indonesia can increase the chances of PPTK Gambung's green tea factory to become the largest, by producing good quality green tea, optimally using new processing tools and machines, and increasing the competence of the workforce.

3.4. Energy Saving in Withering Process

In the green tea processing process at the PPTK Gambung Green Tea Factory, the largest energy consumption (without indirect energy) is in the withering process, which is 46.402% of the total processing energy use, with an efficiency of 28% in the withering process. The use of energy in the withering process is divided into 3 parts of energy that play a role, where 0.105% comes from biological energy, 95.312% comes from fuel energy, and 4.583% comes from electrical energy. The fuel used in the withering process is wood pellets which is an alternative energy source because the availability of raw materials is easy to find, namely from wood waste. According to Sanusi *et al*. (2011), this wood pellet fuel energy has an energy unit value of 18.42 MJ/kg, and is consumed by a rotary panner machine. The energy produced is in the form of heat to heat tea shoots by flowing hot air with temperatures ranging from 90 – 100 °C. The average rate of use of wood pellet fuel is 165 kg/h for the engine capacity (rotary panner) of 1,109 t/h. The use of wood pellet fuel is influenced by the characteristics of the wood pellet and also the content in it, such as raw materials, specific calorific value, carbon value, ash content, and water content.

Energy savings that can be done in the withering process is by way of maintenance and replacement of damaged machine parts. The treatment that needs to be done is to clean the dust from the combustion of wood pellets on the burner so that energy absorption is more optimal, and control the leakage in the rotary panner so that the combustion products in the burner do not enter the hot temperature that the rotary panner flows during withering, so that the quality and quality green tea can be awake (Telmo & Lousada, 2011).

There are three recommended periodic maintenance or maintenance, namely daily maintenance carried out before and after processing, monthly routine maintenance, and incidental maintenance in case of damage to the machine. The maintenance carried out must still consider the occupational health and safety aspects for workers. Cleaning dust from burning wood pellets on the burner should be done before or after processing when the engine is turned off. The burner on the rotary panner remains on in the event of a power outage, so to ensure the health and safety of the workers, it is recommended to use a generator set (generator) at the PPTK Gambung Green Tea Processing Factory, so that the machine can still be operated even if a blackout occurs. Provision of spare parts for machines in the warehouse also needs to be done so that when there is damage to the machine it can be repaired immediately so that it does not interfere with the green tea processing process.

3.5. Energy Saving on Packing

The packaging of tea at the PPTK Gambung Green Tea Factory is carried out using burlap and plastic sacks with a packing of 40 kg of dry tea/pack. The packaging process contributes an indirect energy of 0.316 MJ/kg and until now this material cannot be

replaced. An alternative solution to reduce the amount of indirect energy is by changing the concept of packaging size to 55 kg of dry tea/pack. This is because the packaging of burlap sacks ranges from 35-60 kg of tea/sack. The calculation of packing savings is as presented in Table 3.

Table 3. Indirect energy saving opportunities in the packaging process

Packaging Size	Quantity of dry tea (ton)	Burlap Sack (unit)	Inner Plastic (unit)	Energy for Burlap Sack (MJ/kg)	Energy for Inner Plastic (MJ/kg)	Total Energy (MJ/kg)
40 kg/pack	3,308	83	83	0.145	0.012	0.157
55 kg/pack	3,308	60	60	0.106	0.008	0.114

The concept of changing the packaging size from filling 40 kg of dry tea with an energy requirement of 0.157 MJ/kg to a filling of 55 kg of dry tea/pack with an energy requirement of 0.114 MJ/kg can save energy use in the packaging process up to 0.043 MJ/kg of dry tea (27%). From the economic point of view, changing the size of the packaging can save production costs to around Rp. 93,605 per production at the price of burlap sacks Rp. 3,400/pc and the price of the inner plastic is Rp. 750/pc. If the daily production produces the same dry green tea which is 3,308 tons, then the cost that can be saved in one year for 312 days of production is Rp. 29,204,760.

3.6. Energy Saving in Power Supply System

The greatest use of electrical energy occurred in drying II, which was 0.274 MJ/kg. In drying II, the average process input mass is 8,384 tons which is then dried using a rotary dryer and ball tea machine (Kaleemullah & Kailappan, 2005). The ball tea used has a capacity of 250 kg of dry tea with a total of 16 machines with electricity consumption of 1,982,015 kWh. Energy savings that can be done is to increase the capacity of the ball tea machine by modifying the machine, so as to reduce the number of uses of the ball tea machine in order to save energy consumption and electricity costs. If the capacity of ball tea can be increased to 400 kg of dry tea, then with the number of machines as many as 16 units the electricity usage can be reduced to 1,832,815 kWh with efficiency (7.5%), so that there will be a savings in electricity usage of 149.2 kWh. If the electricity price is Rp. 1,352/kWh and the operation of the ball tea machine in 1 month is 26 working days, the cost of green tea processing electricity consumption can be saved by Rp. 62,936,141 annually.

4. CONCLUSIONS

The conclusions that can be obtained from research on energy analysis in green tea processing at the PPTK Gambung Green Tea Factory are: (a) Green tea processing for one shoot tea process requires 51.141 MJ/kg energy, the total indirect energy use is 46,764 MJ/kg or 91.44%, the total use of biological energy is 0.01 MJ/kg or 0.02%, and direct energy use of 4,366 MJ/kg or 8.54%. (b) The greatest energy occurs in the withering process which reaches 17,364 MJ/kg. where the use of biological energy is 0.002 MJ/kg and indirect energy use is 15.333 MJ/kg or 88.303%. (c) The efficiency of energy use in the withering process is 27% by changing the packaging size from 40 kg to 55 kg of dry tea. (d) The efficiency of using electricity in the drying process II is 7.5% by modifying the capacity of ball tea from 250 kg to 400 kg.

REFERENCES

Abdullah, K., Irwanto, A.K., Siregar, N., Agustina, S.E., Tambunan, A.H., Hartulistiyoso, E., & Purwanto, Y.A. (1990). *Energi dan Listrik Pertanian.*   Japan International Cooperation Agency. Institut Pertanian Bogor. Bogor

Ang, B.W., & Choong, W.L., Ng, T.S. (). Energy security: Definitions, dimensions, and indexes. *Reneweble Energy and Sustainable Energy Review*, *42*, 1077-1093. https://doi.org/10.1016/j.rser.2014.10.064

Anova, A. (2017). Upaya PT. Perkebunan Nusantara VIII dalam mengembangkan ekspor teh hitam ke Malaysia. *Jurnal Online Mahasiswa Fakultas Ilmu Sosial dan Ilmu Politik. Universitas Riau*, *4*(2), 1-13.

BPS (Badan Pusat Statistik). (2017). *Statistik Teh Indonesia 2017*. Badan Pusat Statistik Republik Indonesia. Jakarta.

Biantoro, A.W. (2017). Analisis perbandingan efisiensi energi pada gedung P Kabupaten Tangerang dan gedung tower UMB Jakarta. *Jurnal Teknik Mesin Mercu Buana*, *06* (3), 164-173. https://dx.doi.org/10.22441/jtm.v6i3.1966

Cervinka, V. (1980). Fuel and energy efficiency. In *Handbook of Energy Utilization in Agriculture* USA.

DEN (Dewan Energi Nasional). (2014). *Outlook Energi Indonesia 2014*. ISBN 978-602-1328-02-6. Jakarta.

Hasan, M.I. (2002). *Pokok-pokok Materi Metodologi Penelitian dan Aplikasinya.* Ghalia Indonesia. Jakarta.

Herwanto, T., Nurjanah, S., Saukat, M., Hafidz, S. 2018. Analisis energi pada proses pengolahan teh hitam ortodoks (Studi kasus PT. Perkebunan Nusantara VIII Kebun Gedeh, Desa Sukamulya, Kecamatan Cugenang, Kabupaten Cianjur, Jawa Barat). *Jurnal Teknotan*, *12*(1), 65-72. https://doi.org/10.24198/jt.vol12n1.7

Hu, Q., Xu, J., & Pang, G. (2003). Effect of selenium on the yield and quality of green tea leaves harvested in early spring. *J. Agric. Food Chem.*, *51*(11), 3379–3381. https://doi.org/10.1021/jf0341417

International Tea Committee. (2017). *Annual Bulletin of Statistics 2017*. International Tea Committee. London.

Kaleemullah, S., & Kailappan, R. (2005). Drying kinetics of red chillies in a rotary dryer. *Biosystem Engineering Journal*, *92*(1), 15-23. https://doi.org/10.1016/j.biosystemseng.2005.05.015

Mancini, E., Beglinger, C., Drewe, J., Zanchi, D., Lang, U.E., Borgwardt, S. 2017. Green tea effects on cognition, mood and human brain function: A systematic review. *Phytomedicine Journal*, *34*, 26-37. https://doi.org/10.1016/j.phymed.2017.07.008

Notoatmodjo, S. (2005). *Metodologi Penentuan Sampel Penelitian Kesehatan*. PT. Rineka Cipta. Jakarta

Kusuma, W. (2008). Analisis Pucuk Tanaman Teh (*Camellia sinensis* (L.) O. Kuntze) Di Perkebunan Rumpun Sari Kemuning, PT Sumber Abadi Tirtasentosa, Karanganyar, Jawa Tengah. *Skripsi*. Fakultas Pertanian, Institut Pertanian Bogor, Bogor

Nurudin. (2016). *Kebutuhan Energi: Indonesia Tertinggi di Asean*. Bisnis Indonesia. Jakarta

Rohdiana, D. (2015). Teh: Proses, karakteristik, dan komponen fungsionalnya. *Foodreview Indonesia*, *X*(8), 34-38.

Sabbaghi, A., & Vaidyanathan, G. (2004). SWOT analysis and theory of constraint in information technology projects. *Information System Education Journal*, *2*(23), 3-18.

Santoso, J. (2008). *Petunjuk Teknis Pengolahan The*. 2nd ed. PPTK Gambung, Bandung.

Sanusi, D., Syahidah, S., & Mahdi, M. 2011. *Karakteristik Pellet Kayu Sengon*. Fakultas Kehutanan. Universitas Hasanuddin. Makassar.

Setiawan, T. (2010). Audit Energi Pada Sistem Pengolahan Pucuk Teh Menjadi Teh Hitam Orthodox Di PT. Perkebunan Nusantara VIII Kebun Cisaruni, Garut Jawa Barat. [*Undergraduate Thesis*]. Fakultas Teknologi Pertanian. Institut Pertanian Bogor. Bogor.

Sugiyono. 2011). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Afabeta. Bandung

Taulo, J.L., & Sebitosi, A.B. (2016). Material and energy flow analysis of the Malawian tea industry. *Reneweble Energy and Sustainable Energy Review*, *56*, 1337-1350. https://doi.org/10.1016/j.rser.2015.11.072

Telmo, C., & Lousada, J. (2011). Heating values of wood pellets from different species. *Biomass and Bioenergy Journal*, *3*(7), 2634–2639. https://doi.org/10.1016/j.biombioe.2011.02.043